Renewable and Sustainable Energy Reviews 16 (2012) 3200–3205

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

What makes people adopt improved cookstoves? Empirical evidence from rural northwest Pakistan

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ARTICLE INFO

Article history:
Received 27 March 2011
Accepted 18 February 2012
Available online 22 March 2012

Keywords:
Deforestation
Biomass
Indoor pollution
Improved cookstoves
Regression analysis

ABSTRACT

Large dependence of the world population on biomass fuels for domestic energy consumption is one of the major anthropogenic causes of deforestation worldwide. The use of biomass in inefficient ways in rural areas increases fuelwood demand of a household. Development of the improved biomass stove programs in the 1970s has been one of the efforts to reduce burden on biomass resource base through reliable and efficient methods of energy consumption. However, despite having multiple economic, social, environmental, and health benefits; the improved stove dissemination programs failed to capture worldwide recognition. A wide array of socio-cultural, economic, political, and institutional barriers contributes to the low adoption rate of such programs. Drawing on field work surveys in rural northwest Pakistan, this paper provides empirical evidence of individual, household, and community level variables that play a vital role in the adoption of improved cookstoves. The study is based on primary data collected from 100 randomly selected households in two villages of rural northwest Pakistan. Using regression analysis, the study depicts that education and household income are the most significant factors that determine a household willingness to adopt improved biomass stoves. The study concludes that the rate of adoption could substantially be improved if the government and non-governmental organizations (NGOs) play a greater role in overcoming the social, economic, cultural, political, and institutional barriers to adopting improved cooking technologies.

Contents

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1364-0321/$ – see front matter
doi:10.1016/j.rser.2012.02.038

1. Introduction

Adequate forest cover is essential for the sustainability of an ecological system both in developed as well as developing countries. However, the uncontrolled and unsustainable cutting of forests worldwide is a serious threat to environmental sustainability. Forests are globally depleted at a rate faster than they can grow. Both natural and anthropogenic factors contribute to forest depletion and degradation worldwide. Human activities are globally recognized as the principal cause of deforestation [9]. Poverty and other socioeconomic factors force people in the developing world to exploit forest resources for domestic energy consumption and other commercial gains [18,51].

One of the main reasons of global deforestation is increased reliance of a large proportion of the world population on forests for their energy needs. About 2.5 billion people worldwide depend on woody and non-woody (dung, agricultural waste, twigs and shrubs) biomass fuel and coal for their domestic energy requirements [20,37,40,43,49,50,53]. The intensity of biomass use increases in those areas where people have relatively low income levels and live close to the forestlands. This intensive use of biomass posses several environmental and health related threats. About 3% of the global burden of diseases is caused by wood smoke, which results in 1.6 million premature deaths every year including 900 thousand children under five [38,42,52,55]. Millions more face other problems such as chronic respiratory diseases, asthma, breathing difficulties and wheezing, reduced lung functions, stinging eyes, sinus problems, and low-birth-weight babies [12–14,48,53,54].

With increase in the household income level, however, energy consumption patterns change and people move-up the energy ladder from fuelwood to kerosene, charcoal, coal, LPG (liquefied petroleum gas), and natural gas [5,38]. The upward shift is most notable in urban areas as people in rural areas mostly continue to rely on biomass fuels because of its availability and affordability [4,34]. One of the factors that results in high demand for fuelwood is its low combustion efficiency [39,41]. In order to maintain low demand for fuelwood to reduce pressure on the local forest reserves, the development and dissemination of energy efficient cooking technology such as improved biomass stoves is considered as one of the most technically feasible, socially reliable, and economically viable interventions available [3,7,29,34]. The improved stove programs focusing on energy efficiency began in the 1970s following high increase in oil prices [3,4,17]. Since then several hundred improved cookstove programs have been launched worldwide, ranging from local NGO projects to nationwide initiatives such as in Nepal, China and Mexico [22,26,35]. The energy-efficient and inexpensive stoves programs not only reduce pressure on the biomass resource base but also minimize household expenditures on biomass, shorten the time required for fuelwood collection, and reduce concentration of smoke and indoor pollution [4,19,22,27]. A growing source of interest has also come from trading carbon offsets from improved cookstove programs on carbon markets for voluntary reductions, or as part of Clean Development Mechanism (CDM) of the Kyoto Protocol [24,33,44].

The main beneficiaries of the improved cookstove programs are the most vulnerable groups in a society, i.e. women, children, and low income groups [28,50,56]. In many developing countries fuelwood collection and use is the primarily responsibility of women who devote a considerable time to fuel collection. Kumar and Hotchkiss [31] estimated that women in the hill areas of Nepal spent 2.5 h/day on fuel collection. Similarly, Karekezi et al. [28] recorded that in Botswana, the average time spent on fuelwood collection was about 3.3 h. This research found that women sometimes spent up to 6 h/day collecting fuelwood. With improved cookstove program, the combustion efficiency increases which not only reduces cooking time but also minimizes the fuelwood demand of a household [7,10,23]. This not only reduces household cash outlays for fuelwood, but also reduces time spent by women collecting fuelwood.

Yet although the social, economic, and environmental benefits of the improved stove programs seem to be rather clear, the rate of adoption is not as fast as hoped and anticipated. A number of socioeconomic factors such as lack of knowledge about the costs and benefits of improved cooking technology [11,39], income level of the household, and lack of proper monitoring systems of the stove programs are responsible for slow adoption rates. Studies reveal that middle-income households in parts of Africa have adopted improved stoves far more quickly than low income households [25]. Similarly, education of women in particular as well as improved awareness regarding the relative advantages of improved cookstoves has been significant factors for improved cookstoves adoption in Sudan [39].

1.1. Biomass use in Pakistan

A majority of Pakistan's population (62%) resides in rural areas and semi-urban slums [15]. This population largely depends on agriculture and the natural resource base for their livelihoods. Pakistan is a country with a very low area under forest cover. The total area of the country under forest is only 4.22 million hectares which accounts for 5% of the total area [2,47]. Besides, the country faces serious depletion of the already scant forest reserves. Since a large number of people in rural areas in Pakistan depend on forests for their livelihood, fuelwood and shelter, the general perception among planners is that over population is the primary driver of forest depletion and degradation. Moreover, people living in close vicinity to forestlands sometimes use the forests in unsustainable ways to satisfy their domestic energy and other commercial needs [32].

Pakistan is already an energy deficient country. Electricity from the national grid and natural gas reserves are not sufficient and affordable, particularly to the relatively low income rural population. The situation is more serious in the case of petroleum based fuels because of their high prices. This leaves people largely dependent on local forests to satisfy their domestic energy needs. A major problem related to biomass consumption is the use of inefficient and traditional[1] cooking technology. Three-stone or open-mud stoves are commonly used for cooking and heating in rural areas in Pakistan. These stoves are not only known for their low thermal efficiency but also for high wood consumption, and increased emission of green house gases (GHGs). Studies have shown that health hazards of biomass consumption have been more in the areas where inefficient cooking technology is frequently used [35,36,45,46,48,57].

1.2. Improved cookstoves in the research area

In order to reduce the social, economic, environmental, and health related risks associated with the use of traditional biomass stoves, some NGOs working in different areas of Pakistan have launched interventions to disseminate improved cookstoves in their project areas. One such program was initiated in Swat in early 1990s by a Pak–Swiss project called Kalam Integrated Development Project (KIDP). In 1998, however, KIDP terminated its activities in Swat for a series of socio-political, financial, and institutional reasons. Nevertheless, a few local manufacturers in the area still produce improved cookstoves variously referred to as project stoves. Like many other rural areas in developing countries, the rate

[1] The traditional use of biomass refers to the basic technology used, such as three-stone fire or inefficient cookstove, and not the resource itself [40].

Table 1
Summary statistics of the variables used in binary logistic model.

Description	Mean	Std deviation
Households with improved cookstoves	0.20	0.40
Age of respondent (years)	37.0	12.6
Age of respondent squared	1525	1074
Respondent qualification (years)	7.29	5.48
Log of total landholding	0.36	0.65
Total household members	7.92	3.35
Total household working members	1.48	0.81
Total monthly income of the household (in 000s Pak. Rs)	13.1	10.1
Whether collecting biomass (=1 if collects)	0.45	0.50
Knowledge of traditional biomass hazards (=1 if aware)	0.98	0.14

Source: Field survey, 2010.
$N = 100$.

of adoption of improved cooking technology is very low in the area, yet not discouraging. By using regression analysis, the main goal of this study is to provide empirical evidence of the factors that influence a household decision to adopt improved cooking technology. The study further aims to contribute to the contemporary empirical literature on factors that determine household choice of adoption of improved cookstoves in developing economies like Pakistan [11,35,39].

2. Methodological consideration

2.1. Description of the research area

The study was carried out in Swat District of Khyber Pakhtunkhwa Province[2] in Pakistan from August to October 2010. Swat valley is situated at 266 km northwest of the Federal Capital Islamabad. Besides its natural beauty which has led to Swat being referred to as 'the Switzerland of Pakistan', Swat has recently also become infamous both because of the recent counter insurgency movement in the area, and latterly because of the unprecedented heavy flood in 2010 that devastated the region. However, peace has been now restored in the area and development interventions are in progress at a high pace. Most of the rural population in Swat dwells close to the green hills, covered by forests and vegetation. Rural masses cut and gather woodfuel, twigs, and other shrubs and use them as fuel for domestic purposes. The majority of people in the area rely on traditional practices of biomass use. However, energy efficient technology, such as improved cookstoves, is also available in the area.

2.2. Research methods

The research was conducted in two villages in the Swat District. The socioeconomic characteristics, demographic structures, topographic conditions, land tenure system, livelihood structures, and living conditions are almost the same in all neighboring villages of Swat. Therefore, the findings of the study could potentially be generalized to all villages in the area. A semi-structured questionnaire was administered to collect primary data from the recipients of the energy services – the households. The questionnaire included information about the socioeconomic characteristics of the people, available energy sources in the area, and the patterns of cooking practices they were adopting. From each village, 50 households were randomly selected for interviews. Due to some socio-cultural limitations in the field, the interviews were restricted to male respondents only. The Pakhtun (Pathan) tribe living in the research area is known for their strict social and tribal norms such as strict observance of pardah.[3] Furthermore, the household head in that society has a strong influence on the household decisions. The overall sample size for the study was 100 households. Secondary information was collected from the local political leader (the ex-Nazim) and other NGOs working in the area.

The data obtained were analyzed using SPSS (version 16) and STATA (version 11). The dependent variable (adoption of improved cookstoves) was in dichotomous (dummy) form. Hence, binary logistic regression was used to predict the effects of the explanatory (predictor or independent) variables on the dependent (outcome) variable. The descriptive analysis of the variables and outcome of the model is presented in the following sections.

3. The model specification (binary logit model)

A household adoption of improved cookstoves is modeled as a dichotomous variable with values 1 '*if a household adopts improved cookstoves*' and 0 '*if otherwise*'. The probability of a household adoption of improved devices is formulated as a function of individual and household level characteristics. Summary statistics of the predictor variables hypothesized to influence a household willingness to adopt improved cookstoves are given in Table 1. The predictor variables in the model include attributes of individual and household characteristics that could influence a household decision to adopt improved biomass stoves. Individual and household characteristics include socioeconomic factors such as age and education of the respondent, family size, household income, total landholding, number of working household members, etc.

3.1. Age of respondent

The age of the respondent has a mean of 36.99 years with a standard deviation of 12.6. To account for the possible non-linear effect of age, the variable age squared was also used in the model. However it is pertinent to mention that age could sometimes have negative effects as older people tend to have a more conservative and risk adverse attitude towards adopting technology and new interventions.

3.2. Qualification of respondent

Qualification level of respondents was measured as '*years of schooling*'. Qualification was hypothesized as a proxy for more awareness about the pros and cons of using improved cooking devices. The likelihood of low educational level, however, was anticipated in such a remote rural community. The mean of the

[2] Khyber Pakhtunkhwa formerly, North West Frontier Province (NWFP) is one of the four provinces of Pakistan, viz., Punjab, Sind, and Baluchistan.

[3] Pardah mean segregation of female from male in an Islamic society [21].

Table 2
Determinants of household adoption of improved cookstoves in the area.

Dependent variable	Independent variables	Regression coefficients
Households with improved cookstoves	Age of respondent	0.02
	Age of respondent squared	−0.004
	Respondent qualification	0.838**
	Log of total landholding	−2.084
	Total household members	0.082
	Total household working members	−13.05**
	Total monthly income of the household	0.001**
	Biomass collection	−1.67**
	Knowledge of traditional biomass hazards (=1 if aware)	15.03
	Constant	−16.23
N		100
−2 log-likelihood value		21.59
Model chi[2] [9]		78.49***

** Significant at $p = 0.05$.
*** Significant at $p = 0.01$.

respondent qualification was recorded as 7.29 years with a standard deviation of 5.48.

3.3. Total landholding

Another important variable is total landholding which could significantly influence a household choice to use improved cookstoves. The substantive theoretical importance of including this variable in the model was the fact that acquisition of land is an important determinant of socio-political status in Pakistan. It was expected that a household with more landholding will be more likely to adopt improved cookstoves. However, in order to overcome the linearity issues of the variable [16] a natural log of the total landholding was used as predictor variable.

3.4. Family size

Family size was expected to have a positive influence on the model. It was assumed that families with a large number of household members will be more inclined to adopt improved cookstoves. The mean of the family size in the area was 7.92 persons and the standard deviation as 3.35.

3.5. Number of household working members

The number of working members in a household was also hypothesized to play significant role in a household decision to adopt improved devices. The variable was measured with a mean of 1.48 persons and standard deviation as 0.81.

3.6. Income of the household

Household income was expected to have positive effect as more wealthy households may have higher probability of using improved stoves. Income of a household was measured as total sum of money in Pakistani Rupees (Pak. Rs) earned by all members of the household per month. The mean of a household total income was 13.1 Pak. Rs. (in 1000s) with a standard deviation of 10.1.

3.7. Biomass collection

A household's pattern of biomass collection was considered to have an influence on household's use of improved devices. It was, however expected that a household not collecting biomass itself will use improved stoves. This variable has a mean of 0.45 and standard deviation of 0.500.

3.8. Knowledge of biomass hazards

Knowledge of a respondent regarding hazards of biomass use in an inefficient way was measured as the degree of awareness of the respondent from different sources such as Internet, TV, radio, newspapers, and NGOs working in the area. It was hypothesized that respondents who were aware of the threats of using biomass in traditional manners were more likely to use improved cookstoves. It has a mean of 0.98 and a standard deviation of 0.14.

4. Results and discussion

The descriptive analysis of the dependent variable indicated that only 20% of the sample households in the study area used improved cookstoves. As with many developing countries, this reflects to a low rate of adoption. A number of socioeconomic, cultural, political, and institutional factors contribute to the adoption of improved cooking facilities in different countries. In this particular model, it was hypothesized that some individual and household level variables will play a significant role in a household choice of improved biomass stoves in the research area. The assessment of how much better these variables predict the household adoption of improved stoves is presented in Table 2. The analysis confirmed that the respondent's qualification, total number of working members in a household, total monthly income, and a household choice of whether or not collecting biomass had significant effects on a household adoption of improved biomass stoves.

The qualifications of respondents were used as proxy for awareness of the relative threats and benefits of using improved technology for domestic energy purposes. The more aware (educated) respondents[4] were, the more likely they were to use efficient cooking technologies. The relative advantages of using improved devices, as reported by the respondents, are less fuelwood consumption and thus reduced cash outlays for fuel, efficient cooking, reduced emission of particulate matter (PM), and low health and environmental hazards. The qualification of respondents, as it was anticipated during the model construction, showed a positive effect on a household adoption of improved stoves with a significance level of 0.05. In their study on dissemination of energy-efficient technologies in India, Kumar et al. [30] depicted that low educational attainment was one of the major causes of non-adoption of

[4] Although utilization of cooking devices is responsibility of women, its provision is entirely responsibility of a household head. As the male household head is the major decision-making body, particularly decisions that involve financial outlays, his education (awareness) is more important for any adoption.

improved cooking technologies. Another important predictor variable was total monthly income of the household. The research area is one of the remote areas in northwest Pakistan where people are mostly poor. One of the reasons why people use traditional cooking technologies in rural areas is their low income levels. However, literature suggests that the pattern of household domestic energy consumption changes with increase in the income level [6]. Similarly, Bardhan et al. [8] also concluded that household energy consumption behavior can be explained in terms of the wealth and substitution effects of increases in household income. The effect of the household income on a household willingness to adopt improved devices was statistically significant at $p < 0.05$.

The variables *total number of household working members* and *biomass collection* were significant at 5% probability. The negative signs reveal the reverse effects of these variables. The response categories for the variable biomass collection were 1 '*if collects biomass*' and 0 '*if otherwise*'. This reflects the fact that positive responses in this case were from those households who were relatively less well-off compared with those whose response was '*No*'. In other words, households not collecting biomass were more likely to adopt improved biomass stoves. The negative sign attributes towards the '*Yes*' response of the households collecting biomass who were socio-economically less wealthy.

The age of respondents, both in linear and non-linear terms, total landholding, size of family, and knowledge of biomass hazards did not look likely to be good predictors because their score statistic was non-significant. The most important of these variables was total landholding which is an important determinant of socio-political status in the area. No significance of landholding in this particular model can be attributed to the fact that most of the people in the research area, as confirmed by the preliminary data, were smallholders. In such a case, other factors like household awareness and exposure to outer orientation are most important factors influencing a household's choice of adoption of improved cooking technologies.

Overall fit of the model was measured by the value of Log Likelihood statistics which was 21.59. As we know that the lower values of $-2LL$ indicate that the model is predicting the outcome variable more accurately, the value of $-2LL$ indicates a good fit with the statistical model used in this study. The model Chi-square statistic was also used to assess how much better the model predicts the outcome variable. The overall model was significant at $p < 0.01$.

5. Conclusion

The study supports the argument that the use of improved cookstoves, particularly in rural societies, is important for economic, social, and environmental reasons. The benefits from these stoves have always outweighed the costs of the stoves. While extremely beneficial from an economic, social, environmental, and health perspective, the slow rate of adoption of such stoves is common. A key set of barriers, although varying in different social, economic, cultural, and political situations, contributes to this slow adoption [1,41]. For instance, lack of education of the household members, especially women, reduced participation of women in household decision making processes, low income of the household, lack of knowledge of health and environmental hazards associated with inefficient use of biomass, insufficient funds allocated by governments and NGOs for such programs, and poor monitoring system for the long-term stove use and adoption patterns are among the key factors. In the area in Pakistan that is the subject of this research, it was practically observed, that the most important factors that hinder the pace of adoption are lack of awareness, motivation, and institutional support. The study recommends that government and voluntary organizations should work in parallel to develop pro-poor energy policy frameworks such as dissemination of improved cooking technologies in rural areas. There is a dire need for coordinated, consistent, and focused cooperation of all stakeholders on the supply and demand side. This will not only improve the economic, social, environmental, and health situation in the local context, but will play a pivotal role in achieving the United Nations Millennium Development Goals (MDGs) in a broader context.

Acknowledgments

The study was conducted with financial support by the Higher Education Commission (HEC), Pakistan for which the author is highly indebted. The author is also thankful to Peter Newell, University of East Anglia, UK for his valuable comments on the early draft of this paper, and the anonymous referees for their helpful comments. Special appreciations are also extended to people in the research area for their cooperation and facilitation during data collection, despite being seriously affected by the recent heavy floods.

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